

SPECIAL REPORT

Guidelines for Coronary Angiography

A Report of the American College of Cardiology/American Heart Association Task Force on Assessment of Diagnostic and Therapeutic Cardiovascular Procedures (Subcommittee on Coronary Angiography)

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Preamble

It is becoming more apparent each day that despite a strong national commitment to excellence in health care, the resources and personnel are finite. It is, therefore, appropriate that the medical profession examine the impact of developing technology on the practice and cost of medical care. Such analysis, carefully conducted, could potentially impact on the cost of medical care without diminishing the effectiveness of that care.

To this end, the American College of Cardiology and the American Heart Association in 1980 established a Task Force on Assessment of Diagnostic and Therapeutic Cardiovascular Procedures with the following charge:

The Task Force of the American College of Cardiology and the American Heart Association shall define the role of specific noninvasive and invasive procedures in the diagnosis and management of cardiovascular disease.

The Task Force shall address, when appropriate, the contribution, uniqueness, sensitivity, specificity, indications, contraindications and cost-effectiveness of such specific procedures.

The Task Force shall include a Chairman and four members, two representatives from the American Heart Association and two representatives from the American College of Cardiology. The Task Force may select ad hoc members as needed upon the approval of the Presidents of both organizations.

Recommendations of the Task Force are forwarded to the President of each organization.

The members of the Task Force are: Roman W. DeSanctis, MD, Harold T. Dodge, MD, T. Joseph Reeves, MD, Sylvan Lee Weinberg, MD and Charles Fisch, MD, Chairman.

The Subcommittee on Coronary Angiography was chaired by John Ross, Jr., MD, and included the following members: Robert O. Brandenburg, MD, Robert E. Dinsmore, MD, Gottlieb C. Friesinger II, MD, Herbert H. Hultgren, MD, Carl J. Pepine, MD, Elliot Rapaport, MD, Thomas J. Ryan, MD, Sylvan Lee Weinberg, MD and John F. Williams, Jr., MD.

This document was reviewed by the officers and other responsible individuals of the two organizations and received final approval in March 1987. It is being published simultaneously in *Circulation* and *Journal of the American College of Cardiology*. The potential impact of this docu-

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ment on the practice of cardiology and some of its unavoidable shortcomings are clearly set out in the introduction.

Charles Fisch, MD, FACC

I. Introduction

The American College of Cardiology/American Heart Association Task Force on Assessment of Cardiovascular Procedures was formed to make recommendations regarding appropriate utilization of technology in the diagnosis and treatment of patients with cardiovascular disease. Coronary angiography is one such important technique. The uses of coronary angiography have undergone an extraordinary expansion in the recent past, in part stimulated by the development of improved techniques and new forms of treatment, particularly for patients with atherosclerotic coronary heart disease. This has led to some expansion of the indications for coronary angiography, and in some settings overuse of this procedure has been suggested. Accordingly, it was recommended that this Task Force review current indications and develop guidelines for the use of coronary angiography.

Recommendations concerning the staffing and equipment of laboratories are beyond the scope of this report, and statements concerning the safety of outpatient cardiac catheterization procedures are available (1). The guidelines provided may contribute to limiting overuse of coronary angiography, and it is considered that the proportion of studies in a given laboratory that show entirely normal coronary arteriograms or one or more coronary stenoses of <50% diameter should not exceed approximately 25%.*

This report is not intended to provide strict indications or contraindications to coronary angiography because, in the individual patient, multiple other considerations may be relevant, including the family setting, occupational needs and individual preferences concerning life-style. Rather, the report is intended to provide general guidelines that may be helpful to the practitioner, as well as to various health care agencies.

The primary purpose of coronary angiography is to define the anatomy of the coronary arteries when such information is needed for patient management. This anatomic definition includes assessment of the presence, extent and severity of obstructive atherosclerotic coronary artery disease, coronary artery size, coronary collateral flow, thrombus formation, dynamic obstructions (coronary spasm) or congenital coronary artery anomalies.

Coronary angiography is the only method currently available for defining the details of vascular anatomy in the coronary arteries, and as such it provides the reference standard against which less direct methods for studying the

coronary circulation are judged. Therefore, although it is a relatively expensive procedure, its "cost-effectiveness" cannot be directly compared with other approaches at this time.†

Coronary angiography is used not only in diagnosis but also to assess the appropriateness and feasibility of various forms of therapy aimed directly at the coronary arteries, such as percutaneous coronary angioplasty, coronary artery bypass surgery, thrombolysis or treatments designed to cause regression of atherosclerosis. Finally, information provided by coronary angiography is useful for assessing the results of therapy and in helping to formulate prognosis in patients with coronary artery disease. It should be emphasized that coronary angiography does not provide direct information about the patient's functional capacity and symptoms or the functional significance of a given coronary lesion. Moreover, prognosis has multiple determinants not discernible at angiography which are often key issues in clinical decision making.

The format of this report includes, first, some general considerations concerning the accuracy of coronary angiography, contraindications to its use, and risks of the procedure. The applications of coronary angiography in specific disease states are then presented and briefly discussed.

II. General Considerations

A. Accuracy of Coronary Angiography

Coronary angiography continues to be the standard for assessing coronary artery obstructive disease, but some limitations of the technique are important to recognize. Conventionally, the degree of coronary artery obstruction is estimated as the percent reduction of luminal diameter, determined by comparing the diameter at the site of maximal reduction to that in adjacent areas that appear either normal or only minimally diseased. This conventional approach has been clinically useful and is the one most widely applied. Nevertheless, there is significant interobserver variability in the conventional interpretation of coronary artery obstructions, and quantitative techniques that substantially reduce interobserver variability are sometimes used (3-5), including application of digital subtraction angiography (6) together with automated techniques that employ manual or computerized border detection or video densitometry. Some digital techniques currently are in use in clinical practice, but application of these promising approaches is not yet widespread.

Some studies have suggested that when the degree of obstruction assessed by coronary angiography is compared with that found at postmortem examination, significant

*Based on the registry of over 20,000 studies in a large multicenter trial (Coronary Artery Surgery Study) in which somewhat less than 20% of the population undergoing coronary angiography had a normal or near normal study (2).

†Outpatient cardiac catheterization in association with techniques for assessing the functional significance of coronary lesions is an emerging approach that may improve cost-effectiveness in the future.

underestimation of atherosclerosis by coronary angiography can occur (7,8). However, quantitative study of coronary obstructions when postmortem coronary angiography is performed with the arteries fixed at physiologic intraluminal pressures shows excellent agreement with direct postmortem measurements (3). It should be noted that postmortem studies, in contrast to coronary angiography, do not detect changes in coronary caliber due to altered coronary vascular smooth muscle tone or to thrombus that has undergone spontaneous lysis.

Techniques to estimate coronary flow reserve from peak coronary flow velocity during reactive hyperemia suggest that minimal absolute coronary stenosis diameter correlates better than the percent diameter reduction with the functional importance of the stenosis (9,10). This finding may relate to unrecognized diffuse narrowing of so-called normal coronary artery segments.

B. Contraindications to Coronary Angiography

All contraindications are relative and best considered by determining whether or not coronary angiography is needed in an emergency or elective setting. In an emergency setting, information obtained by coronary angiography can be life-saving and there may be no contraindications. Examples of such emergency settings are acute myocardial infarction in a candidate for revascularization therapy; mechanical complication early after myocardial infarction that cannot be managed using medical therapy (such as suspected ventricular septal defect or papillary muscle rupture), the presence, in some patients, of unstable angina refractory to medical management, suspected severe aortic stenosis in the patient with refractory heart failure or myocardial ischemia, acute aortic root dissection associated with myocardial ischemia or emergency assessment of a prospective cardiac transplant donor.

Relative Contraindications:

- a. Recent stroke (within 1 month)
- b. Progressive renal insufficiency
- c. Active gastrointestinal bleeding
- d. Fever which may be due to infection
- e. Active infection
- f. Short life expectancy due to other illnesses such as cancer or severe pulmonary, hepatic or renal disease
- g. Severe anemia
- h. Severe uncontrolled systemic hypertension
- i. Severe electrolyte imbalance
- j. Severe systemic or psychologic illness in which prognosis is doubtful or behavior is unpredictable producing undue risk of cardiac catheterization
- k. Very advanced physiologic (not chronologic) age
- l. Patient refusal to consider definitive treatment such

as angioplasty, coronary artery bypass surgery or valve replacement

- m. In patients in unstable condition, lack of a cardiac surgical team in the hospital (such patients refractory to maximal medical therapy should generally be transferred to a center where surgical backup is immediately available). Under special circumstances, when the condition of a hospitalized patient can be readily stabilized such as by use of balloon counterpulsation, coronary angiography might be undertaken in the hospital in the absence of a cardiac surgical team provided that well defined mechanisms are in place for rapid referral and acceptance of such patients by a hospital in which emergency surgery or angioplasty can be carried out with minimal delay*
- n. Digitalis intoxication
- o. Documented anaphylaxis during previous exposure to angiographic contrast material; in most patients with a history of an immediate generalized anaphylactoid reaction to contrast material, the reactions do not constitute anaphylaxis and these individuals can safely undergo coronary angiography using premedication with corticosteroids and antihistamines (11)

It should be recognized that most of these conditions may be temporary or reversible, allowing relatively safe catheterization when the condition is corrected or stabilized.

C. Risks of Coronary Angiography

Overall, coronary angiography is, and should be, very safe. The risk to life should average $<0.2\%$, and the risk of major adverse effects (for example, stroke, myocardial infarction or major bleeding) should be $<0.5\%$ (12). However, certain groups at higher risk can be identified before catheterization or on visualization of the coronary arteries. These individuals often have increased risk predicted by exercise testing (13) (for example, abnormal blood pressure response or >2 mm of ST segment depression in multiple leads at a relatively low heart rate). Other characteristics of increased risk for complications during coronary angiography include patients with critical left main coronary stenosis, severe three vessel disease ($>90\%$ stenosis in each of three vessels), multivessel disease with left ventricular dysfunction (ejection fraction $\leq 35\%$), critical aortic valve stenosis and advanced age (14). Despite higher risk of complications in some patients, the risk/benefit ratio may be

*This statement is in no way intended to change current policy of the American College of Cardiology and the American Heart Association, published in *Circulation* (Vol. 73, No. 3, p. 21, 1986) which states that "The ACC and the AHA do not approve the use of free-standing, non-hospital based cardiac catheterization laboratories."

favorable and the information obtained from the study required to make an appropriate decision.

D. Associated Procedures

A number of associated procedures are often performed in association with coronary angiography, as described in Appendix A. These include a venous line and hemodynamic measurements in the aorta and left ventricle. Left ventriculography is normally a part of coronary angiography, although it may be excluded in certain high risk patients if reliable noninvasive methods of assessing left ventricular function are available. Other associated procedures that are sometimes but not routinely required include right heart catheterization, placement of a temporary pacemaker, selective internal mammary artery angiography, vein bypass graft angiography, aortic root angiography and a variety of transcatheter procedures such as coronary angioplasty (see Appendix A).

III. Classification of Applications of Coronary Angiography

In considering the use of coronary angiography in specific disease states, the following classification is used throughout this report:

Class I: Conditions for which there is general agreement that coronary angiography is justified. A Class I indication should not be taken to mean that coronary angiography is the only acceptable diagnostic procedure.

Class II: Conditions for which coronary angiography is frequently performed, but there is a divergence of opinion with respect to its justification in terms of value and appropriateness.

Class III: Conditions for which there is general agreement that coronary angiography is not ordinarily justified.

Specific disease states are considered under the following categories: known or suspected coronary heart disease, atypical chest pain, acute myocardial infarction, valvular heart disease, congenital heart disease and other conditions.

It is recognized that the field of coronary angiography is undergoing considerable change, and as new insights are gained we can anticipate further refinement of the guidelines for coronary angiography set forth in this document.

IV. Known or Suspected Coronary Heart Disease

A. Asymptomatic Patients

Asymptomatic patients with *known* coronary artery disease generally are those who have had a previous myocardial infarction or have undergone coronary bypass surgery or angioplasty (asymptomatic patients within 8 weeks of an

acute myocardial infarction are considered under VI). Asymptomatic patients with *suspected* coronary artery disease generally are those who have rest or exercise-induced electrocardiography (ECG) abnormalities suggesting "silent myocardial ischemia," often associated with other risk factors.

Class I

1. Evidence of high risk* on noninvasive testing.
 - a. *Exercise ECG testing*
Abnormal horizontal or downsloping ST segment depression:†
Onset at heart rate <120/min (off beta-blockers) or ≤6.5 METS‡
Magnitude ≥2.0 mm of depression
Postexercise duration ≥6 minutes
Depression in multiple leads
Abnormal systolic blood pressure response during progressive exercise:§
With sustained decrease of >10 mm Hg or flat blood pressure response (≤130 mm Hg), associated with ECG evidence of ischemia
Other potentially important determinants
Exercise-induced ST segment elevation in leads other than aVR
Exercise-induced ventricular tachycardia
 - b. *Thallium scintigraphy*
Abnormal thallium distribution in more than one vascular region at rest or with exercise, or abnormal distribution (ischemia) associated with increased lung uptake produced by exercise in the absence of severely depressed left ventricular function at rest.
 - c. *Radionuclide ventriculography*
A fall in left ventricular ejection fraction of ≥0.10 during exercise, or a rest or exercise left ventricular ejection fraction of <0.50, when suspected to be due to coronary artery disease.
2. In individuals whose occupation involves the safety of others, for example, airline pilots, bus drivers, truck drivers, air traffic controllers. Also, those in certain occupations that frequently require sudden vigorous

*High risk patients generally are those with reduced life expectancy due to left main or multivessel coronary artery disease, often with impaired left ventricular function.

†Except for patients with ST segment depression at rest, intraventricular conduction defects excluding right bundle branch block, electrolyte abnormalities and those receiving certain drugs such as a digitalis glycosides, who frequently develop ST segment depression suggestive of ischemia during exercise testing. Recommendations in this section based on ECG criteria during exercise may not apply if these conditions are present.

‡Energy expenditure at rest, equivalent to an oxygen uptake of approximately 3.5 ml O₂/kg body weight per min.

§A decline in systolic blood pressure may occur in some patients without heart disease during sustained maximal exercise, or if certain medications are in use at the time of the exercise test.

activity, for example, firefighters, police officers, athletes.

3. After successful resuscitation from cardiac arrest that occurred without obvious precipitating cause when a reasonable suspicion of coronary artery disease exists.

Class II

1. The presence of ≥ 1 but < 2 mm of ischemic ST depression during exercise, confirmed as ischemia by an independent noninvasive stress test (radionuclide thallium or ventriculographic study, or two-dimensional echocardiographic study, but without criteria for high risk as listed in Class I, 1b and 1c).
2. The presence of two or more major risk factors* and a positive exercise test in male patients without known coronary heart disease.
3. The presence of prior myocardial infarction with normal left ventricular function at rest and evidence of ischemia by noninvasive testing, but without high risk criteria (Class I, 1).
4. After coronary bypass surgery or percutaneous transluminal angioplasty when there is evidence of ischemia by noninvasive testing.
5. Before high risk noncardiac surgery† in patients who have evidence of ischemia by noninvasive testing.
6. Periodic evaluation of patients after cardiac transplantation.

Class III

1. As a screening test for coronary artery disease in patients who have not had appropriate noninvasive testing.
2. After coronary bypass surgery or percutaneous transluminal angioplasty when there is no evidence of ischemia, unless with informed consent for research purposes.
3. The presence of an abnormal ECG exercise test alone, excluding the categories listed in Classes I and II.

B. Symptomatic Patients

Symptoms are defined in accordance with the Canadian Cardiovascular Society classification (Appendix B).

Class I

1. Angina pectoris that has proved *inadequately responsive* to medical treatment, percutaneous transluminal angioplasty thrombolytic therapy or coronary bypass surgery. "Inadequately responsive" is taken to mean that patient and physician agree that angina significantly interferes with a patient's occupation or ability to perform his or her usual activities.

*Smoking, hypertension, hypercholesterolemia, positive family history, diabetes mellitus.

†For example, carotid endarterectomy, abdominal or thoracic aneurysmectomy, iliofemoral bypass surgery.

2. Unstable angina pectoris

- a. Acceleration with increased severity and frequency of chronic angina pectoris within the past 2 months, despite medical management, including onset of angina at rest.
- b. New onset (within 2 months) of angina pectoris which is severe or increases despite medical treatment.
- c. Acute coronary insufficiency, with pain at rest usually of ≥ 15 minutes' duration, associated with ST-T wave changes, within the preceding 2 weeks.
3. Prinzmetal's or variant angina pectoris
4. Angina pectoris (even of Canadian Cardiovascular Society class I or II severity, see Appendix B) in association with any of the following:
 - a. Evidence of high risk as manifested by:

Exercise ECG testing

In addition to high risk findings listed in section IVA, Class I, 1a: failure to complete stage II of Bruce protocol or equivalent work load (≤ 6.5 METS with other protocols; see METS definition under section IV, Class I, 1a) due to ischemic cardiac symptoms. Exercise heart rate at onset of limiting ischemic symptoms of < 120 /min (off beta-blockers).

Radionuclide exercise testing (see section IVA, Class I, 1b and 1c).

- b. The coexistence of a history of myocardial infarction, a history of hypertension and ST segment depression on the baseline ECG.
- c. Intolerance to medical therapy because of uncontrollable side effects.
- d. An occupation or lifestyle that involves unusual risk, or "need to know" for insurance or job-related purposes (see section IVA, Class I, 2).
- e. Episodic pulmonary edema or symptoms of left ventricular failure without obvious cause.
5. Before major vascular surgery, such as repair of an aortic aneurysm, iliofemoral bypass or carotid artery surgery, if angina pectoris is present or there is objective evidence of myocardial ischemia.
6. After resuscitation from cardiac arrest (ventricular fibrillation or standstill) or from sustained ventricular tachycardia in the absence of acute myocardial infarction.

Class II

1. Angina pectoris (even of Canadian class I or II severity) in the following groups:
 - a. Female patients < 40 years of age with objective evidence of myocardial ischemia by noninvasive testing.
 - b. Male patients < 40 years of age.
 - c. Patients < 40 years of age with previous myocardial infarction.

- d. Patients requiring major nonvascular surgery (intraabdominal, intrathoracic, and so on) if there is objective evidence of myocardial ischemia.
- e. Patients who show a progressively more abnormal exercise ECG or other noninvasive stress test on serial testing.
2. The presence of Canadian class III or IV angina which, with medical management, changes to class I or II when other studies suggest absence of high risk (see section IVA, Class I, 1).
3. Patients who cannot be risk stratified by other means; for example, those unable to exercise because of amputation, arthritis, limb deformity or peripheral vascular disease.

Class III

1. The presence of mild, clinically stable (Canadian class I or II) angina pectoris in patients who do not have impaired ventricular function, or exercise studies suggesting high risk (see section IVA, Class I, 1) or other criteria listed under Class I and II.
2. The presence of well controlled angina pectoris (Canadian class I or II) in patients who are clearly not candidates for bypass surgery or angioplasty because of age or life expectancy limited by other illnesses (for example, cancer). In these patients, age is taken to mean biologic age rather than chronologic age and in most instances would be approximately 80 years of age.

Comments

It is generally agreed that whether or not angina pectoris is present:

1. The existence or absence of coronary artery disease should be established with reasonable probability in patients in whom coronary artery disease is suspected.
2. Patients with coronary artery disease who are at high risk for future cardiac events should be identified.

High risk patients generally are those likely to have reduced life expectancy due to left main or multivessel disease and ischemia, particularly if these are accompanied by impaired left ventricular function. The performance of coronary angiography in all patients, whether symptomatic or asymptomatic, with known or suspected coronary artery disease clearly would be very costly. Noninvasive tests, including exercise ECG testing and radionuclide myocardial imaging or ventriculography, are of value for detecting patients with suspected coronary artery disease, as well as for identifying patients who are at high risk, and they are considerably less costly than coronary angiography. However, it is not clear at present whether the use of these noninvasive tests in screening for the detection of severe ischemia and high risk is more or less cost-effective than coronary an-

giography alone. Of course, coronary angiography alone cannot always ascertain the functional significance of coronary stenoses. In the absence of definitive cost-effectiveness data, our recommendations are based on the demonstrated value of the proposed noninvasive tests as screening procedures for identifying induced ischemia and high risk patients.

The criteria cited above for high risk during exercise ECG testing have been stated in a joint ACC/AHA Task Force report (13), which also emphasized the difficulties in interpreting ECG changes in women with a low pretest likelihood of disease. Also, it should be noted that the majority of apparently healthy men who have a positive exercise ECG test (without high risk criteria), and who lack other risk factors, do not have significant coronary artery disease (15).

Radionuclide techniques have higher specificity than the exercise ECG for detecting the presence of coronary artery disease and are of value in detecting multivessel coronary artery disease, as summarized in the ACC/AHA Guidelines for Clinical Use of Cardiac Radionuclide Imaging (16). Patients with coronary artery disease and defects on exercise-thallium imaging in more than one vascular area, or with redistribution (ischemia) and increased lung uptake are at increased risk (16). Patients at increased risk also can be identified by radionuclide ventriculography that demonstrates a left ventricular ejection fraction <0.50 at rest, decreases $\geq 10\%$ with exercise or fails to exceed 0.50 during exercise particularly in association with new or worsening regional wall motion abnormalities during exercise (16).

Because none of the noninvasive techniques are 100% sensitive and specific, coronary angiography is indicated in those patients whose occupation or lifestyle requires that the presence or absence of coronary artery disease be established with certainty (see section IVA, Class I, 2).

Asymptomatic patients

In addition to its use as a diagnostic tool to establish or exclude coronary artery disease, coronary angiography is also used to guide therapy, that is, the selection of medical or surgical treatment. However, therapeutic recommendations in asymptomatic patients based on the extent of coronary artery disease generally are derived from studies in which the majority of patients had had a previous myocardial infarction (17-20). Furthermore, data from the Coronary Artery Surgery Study, which included both asymptomatic and mildly symptomatic patients without left main coronary artery disease, indicate that only those patients with left ventricular dysfunction—that is, ejection fraction between 0.35 and 0.50—and triple vessel disease demonstrated increased longevity after coronary artery bypass surgery (21). The prognosis of asymptomatic patients without previous myocardial infarction should be as good as, if not better than, that of patients with infarction (22), and in the latter the 5 year mortality rate with medical therapy is approximately 2.4%/year (17). The few prospective data available

in apparently healthy subjects with silent ischemia and angiographically proved coronary artery disease indicate that the 8 year mortality rate is approximately 1.5%/year (23), a figure comparable with the long-term mortality after bypass surgery.

There is varying opinion as to when coronary angiography should be performed in asymptomatic patients in whom noninvasive testing indicates a high probability of coronary artery disease, but who are not at high risk as defined by noninvasive test criteria. In part, this is attributable to the observation that the development of ischemia during exercise testing, other than the high risk type, does not itself indicate a poor prognosis (24), yet a small proportion of patients with left main or severe multivessel coronary artery disease will not be detected by noninvasive techniques. It is in the ostensibly non-high risk group that other factors such as age, occupation or life-style become increasingly important considerations when determining whether coronary angiography should be performed.

Adult patients successfully resuscitated from cardiac arrest generally have extensive coronary artery disease. In the absence of recognized precipitating factors, such as acute myocardial infarction, these patients are at high risk for recurrent cardiac arrest (25), and coronary angiography is of value in determining the underlying cause and planning the most appropriate therapeutic approach.

Patients with peripheral vascular disease frequently have coronary artery disease, which results in considerable morbidity and mortality when they undergo high risk, noncardiac surgery, such as abdominal aneurysmectomy or carotid endarterectomy. Some have advocated routine coronary angiography for all patients undergoing peripheral vascular surgery (26), but others have demonstrated that such patients can undergo surgery without significant risk of perioperative infarction if they do not have angina or prior infarction (27). Initial studies show that patients who have normal thallium distribution during intravenous dipyridamole infusion rarely have a perioperative infarction after peripheral vascular surgery, even if coronary artery disease is present (28). In patients with ischemia induced by exercise or other means, definition of the extent of the coronary artery disease by coronary angiography is important in assessing operative risk and determining the need for coronary revascularization before the noncardiac surgery.

Symptomatic patients

In patients with angina pectoris, recent studies suggest that the severity of angina often does not predict prognosis (29), although patients with very severe angina pectoris (Canadian classes III and IV) have been found to have a better outlook with surgical than with medical treatment (30). Furthermore, there is no relation between the frequency of exertional or rest pain and either the severity of coronary artery disease or the frequency of ischemic episodes documented by continuous ECG recordings (31).

Symptoms are often widely variable from patient to patient and even in the same patient. Accordingly, symptom relief by therapy will also vary widely from patient to patient. For these reasons, given the same case histories, physicians in different practice settings vary widely in their assessment of the proper timing for coronary angiography (32). Therefore, in this report we frequently emphasize use of noninvasive measures of high risk rather than symptoms alone in deciding on the timing of coronary angiography.

Acute pulmonary edema, in the absence of acute myocardial infarction, in patients with coronary heart disease carries a poor prognosis and is usually associated with abnormal left ventricular function (33). Some patients with recurrent pulmonary edema due to myocardial ischemia have adequate left ventricular systolic function and may be benefited by coronary artery bypass surgery (34).

Other clinical data may also be useful in assessing risk, and the coexistence of three or more findings (history of myocardial infarction, history of hypertension, ST segment depression on the rest ECG and New York Heart Association functional class III or IV) were found to identify high risk patients in the medically treated group of the Veterans Administration trial (35).

V. Atypical Chest Pain of Uncertain Origin

Atypical chest pain is defined as single or recurrent episodes of chest pain suggestive, but not typical, of the pain of myocardial ischemia. The discomfort may have some features of ischemic pain together with features of noncardiac pain. Chest pain that has no features of cardiac pain, as well as typical chest pain of myocardial ischemia or angina as determined by a careful medical history, is excluded from this definition.

Class I

1. Atypical chest pain when ECG or radionuclide stress tests indicate that high risk coronary disease may be present (see section IVA, Class 1a to 1c).
2. When the presence of atypical chest pain due to coronary artery spasm is suspected.
3. When there are associated symptoms or signs of abnormal left ventricular function or failure.

Class II

1. Atypical chest pain when noninvasive studies are equivocal or cannot be adequately performed.
2. When noninvasive tests are negative but symptoms are severe and management requires that significant coronary artery disease be excluded.

Class III

1. Atypical chest pain in patients without objective signs of ischemia who have had an earlier technically satisfactory *normal* coronary angiogram for the same chest pain.

Comments

In evaluating the patient with chest discomfort that is atypical for myocardial ischemia, it should be emphasized that coronary artery disease is predominantly a disease of male patients until the seventh decade, when the incidence of disease in female patients becomes equal to that in male patients. The probability of disease in males is related to age and other risk factors. For example, the likelihood of coronary artery disease in a 45 year old man with atypical chest pain is just under 50%. In contrast, coronary artery disease in a premenopausal woman with atypical chest pain is rare, unless multiple risk factors are present. In women with atypical chest pain, an ischemic ST segment response has poor predictive value for coronary heart disease (36).

Patients with chest pain that is clearly of noncardiac origin generally do not require noninvasive studies to rule out myocardial ischemia. Most ECG exercise studies will either be negative or, if abnormal, will usually represent false positive tests, especially in female patients (37-41).

VI. Acute Myocardial Infarction

The management of acute myocardial infarction is rapidly changing. Therefore, indications for coronary angiography and its timing after acute myocardial infarction are topics of controversy and continue to change as experience evolves.

Acute infarction will be considered in three phases. *Evolving infarction* encompasses the initial hours after the onset of chest pain and is the period when intravenous or intracoronary fibrinolytic therapy is increasingly used to reduce mortality and the amount of tissue necrosis. The phase of *completed infarction* begins after the initial hours lasting up to, but not including, predischage evaluation; during this period a relatively small percentage of patients suffer additional complications. The phase of *convalescent infarction* is the ensuing period up to 8 weeks, when pre- and postdischarge assessment, progressive ambulation and rehabilitation take place.

Evolving Myocardial Infarction (initial hours of myocardial infarction)

Class I

None

Class II

1. When coronary angiography can be performed within the first 6 hours after the onset of chest pain in patients who are candidates for revascularization therapy (percutaneous transluminal angioplasty, coronary bypass surgery or intracoronary thrombolysis).
2. After early intravenous thrombolytic therapy when immediate percutaneous transluminal coronary angioplasty or coronary artery bypass grafting is being contemplated.

Class III

None

Completed Myocardial Infarction (after the initial 6 hours up to but not including predischage evaluation)

Class I

1. Recurrent episodes of ischemic chest pain, particularly if accompanied by ECG changes.
2. Suspected mitral regurgitation or ruptured interventricular septum causing heart failure or shock.
3. Suspected subacute cardiac rupture (pseudoaneurysm).

Class II

1. Thrombolytic therapy during the evolving phase, particularly with evidence of reperfusion.
2. Congestive heart failure or hypotension, or both, during intensive medical therapy.
3. Recurrent ventricular tachycardia or ventricular fibrillation, or both, during intensive antiarrhythmic therapy.
4. Cardiogenic shock.
5. When the infarction is suspected to be a consequence of coronary embolization.

Class III

1. Myocardial infarction in which no acute mechanical or surgical intervention is contemplated.

Convalescent Myocardial Infarction (immediate predischage up to 8 weeks)

Class I

1. Angina pectoris occurring at rest or with minimal activity.
2. In selected patients, heart failure during the evolving phase, or left ventricular ejection fraction <45%, primarily when associated with some manifestation of recurrent myocardial ischemia or with significant ventricular arrhythmias.
3. Evidence of myocardial ischemia on laboratory testing: exercise-induced ischemia (with or without exercise-induced angina pectoris), manifested by ≥ 1 mm of ischemic ST segment depression or exercise-induced reversible thallium perfusion defect or defects, or exercise-induced reduction in the ejection fraction or wall motion abnormalities on radionuclide ventriculographic studies.
4. Non-Q wave myocardial infarction.

Class II

1. Mild angina pectoris.
2. Asymptomatic status <50 years of age.
3. The need to return to unusually active and vigorous physical employment.

4. A past history of documented myocardial infarction or stable angina pectoris, or both, present for >6 months before the current infarction.
5. Thrombolytic therapy during the evolving phase, particularly with evidence of reperfusion.

Class III

1. Presence of advanced physiologic age.
2. Coexisting disease judged to be primarily responsible for the patient's prognosis, with a greatly shortened life expectancy.
3. Presence of very advanced left ventricular dysfunction (ejection fraction <20%) in the absence of angina pectoris or evidence of ischemia. An exception is the patient who is a candidate for aneurysmectomy or cardiac transplantation.
4. Ventricular arrhythmias in patients who have no evidence of ischemia symptomatically or on exercise testing, well preserved exercise tolerance and no suggestion of aneurysm formation. An exception may be the patient with sustained, refractory ventricular tachycardia.

Comments

Evolving myocardial infarction (initial hours)

Aggressive treatment of evolving myocardial infarction is being increasingly utilized. This approach evolves from several important developments related to coronary angiography. First is the demonstration that coronary artery thrombosis is present in a high percentage of patients studied early after myocardial infarction (42). Second, coronary angiography can be safely performed in patients with evolving infarction (43), and complex manipulations in coronary arteries can be performed in a relatively rapid manner using percutaneous transluminal coronary angioplasty techniques. Third, coronary angiography has shown that effective recanalization is not achieved in a significant fraction of patients undergoing optimal intravenous thrombolytic therapy. Finally, even with successful reperfusion using intravenous or intracoronary thrombolysis, a stenosis of $\geq 90\%$ often is present at the site of recanalization (44). In addition, data from several large trials of thrombolysis have reported a significant incidence of recurrent ischemia or infarction, or both, after apparently successful thrombolysis alone (45-47). These developments have led some to consider definitive revascularization with early percutaneous transluminal coronary angioplasty, or coronary artery bypass grafting, in addition to intracoronary thrombolytic therapy (44,46). These invasive strategies may be used alone (48-50) or in combination with thrombolysis, but all require coronary angiography in the evolving stage of acute myocardial infarction.

Although there is still dispute concerning the precise role of these aggressive treatments in managing evolving infarction, there is general agreement in several areas (51).

One is that the mortality of patients after acute myocardial infarction, both early and late, is directly influenced by the degree of left ventricular dysfunction which, in turn, is dependent on the size of the infarcted myocardial region. Accordingly, limiting the size of the infarction will lessen the impact of myocardial infarction in terms of left ventricular dysfunction and should improve subsequent survival. It is also agreed that the time interval between the onset of abrupt coronary occlusion and institution of any effective intervention should be relatively brief, probably not more than 4 to 6 hours (47), and shorter when possible. Finally, high grade residual stenosis limits the salvage of tissue and impairs recovery of function (52). Therefore, percutaneous transluminal coronary angioplasty initially or early after thrombolysis may prove to be more effective than thrombolysis alone in salvaging injured myocardium and preserving ventricular function (46,52).

The major difficulty in employing early emergency coronary angiography in the patient with evolving infarction as a prelude to revascularization is logistic. Successful application of this concept demands an adequate transport system and a 24 hour emergency center staffed around the clock with specialists in percutaneous transluminal coronary angioplasty, cardiac catheterization and even cardiovascular surgery. For these reasons, emergency coronary angiography followed by acute revascularization is not a procedure applicable to most patients with evolving myocardial infarction.

In some settings, coronary angiography relatively early during acute myocardial infarction might be reserved for those patients whose evolving infarction appears to involve a substantial mass of myocardium, as judged by clinical features (such as the presence of pulmonary congestion or hypotension due to left ventricular dysfunction), with extensive electrocardiographic changes (usually anterior or anterolateral in location).

A number of newer fibrinolytic agents more clot specific than streptokinase are undergoing clinical investigation in the United States and abroad. These agents will likely become widely used in the intravenous treatment of evolving myocardial infarction and may be utilized as soon as the diagnosis is established.

Completed myocardial infarction (6 hours up to predischarge workup)

The decision to perform coronary angiography at this phase of acute myocardial infarction should be contingent on an estimate of the short-term prognosis (days to several weeks). If the prognosis is judged to be poor on the basis of clinical, electrocardiographic and noninvasive estimates of left ventricular function and continuing ischemia *and* it is judged that outcome can be improved by urgent bypass surgery or percutaneous transluminal angioplasty, then angiography is indicated.

The risks and complications of coronary bypass surgery

appear to be greater in patients who have had a recent transmural myocardial infarction and who have depressed left ventricular function (53), so that it is preferable to allow healing and compensatory changes to occur before proceeding with surgery. Hence, whenever possible, in such patients coronary angiography as a prelude to bypass surgery or percutaneous transluminal coronary angioplasty should be postponed until the convalescent phase.

There is general agreement, however, that patients who experience hemodynamic compromise or clinical heart failure with associated findings to suggest rupture of the intraventricular septum, acute mitral regurgitation or pseudoaneurysm any time in the postinfarction period should undergo prompt cardiac catheterization with appropriate angiographic studies. Most such events occur within the first week of the acute infarction. Over the past 5 years increasing experience suggests that early surgical intervention for ventricular septal rupture results in substantially improved survival; in a recent report of 20 consecutive patients undergoing surgery within 2 days of the septal rupture, 60% survived hospitalization (54), and the use of the intraaortic balloon at the time of cardiac catheterization was considered to reduce the complication rate found in earlier studies. The primary information to be obtained from catheterization is an estimation of left ventricular function and evaluation for associated mitral insufficiency and determination of coronary anatomy.

When unstable postinfarction angina pectoris develops within the first week and remains refractory to medical therapy, there is a 20% incidence of recurrent myocardial infarction or death during hospitalization (55). In addition, in such patients others have shown a 25% mortality rate at 3 months (56) and a 50% mortality rate at 6 months (57). Approximately 10 to 15% of patients with an acute myocardial infarction will develop unstable angina within 7 days (56); in those who fail to respond to intensive medical therapy, coronary angiography with consideration of prompt revascularization by angioplasty or coronary bypass surgery is warranted.

Ongoing clinical trials are examining the efficacy and appropriate timing for revascularization procedures (percutaneous transluminal angioplasty, coronary bypass surgery) after successful thrombolytic therapy, although it is being performed with increasing frequency in the early days after thrombolytic therapy.

There continues to be general agreement that patients recovering from an acute myocardial infarction who are clinically well and without symptoms should not be candidates for coronary angiography at this time merely to delineate anatomy.

Convalescent myocardial infarction (from predischARGE workup to 8 weeks)

This group constitutes the largest segment of patients with acute myocardial infarction considered for coronary

angiography. Depending on the character of the patient population and the nature of the hospital, a large majority of patients with acute myocardial infarction will reach the convalescent phase of infarction without having undergone coronary angiography. The principal indication for angiography at this phase is to identify high risk patients for better long-term management. Although an average mortality rate of 6 to 10% for the first year after discharge following recovery from myocardial infarction is usually cited, a number of the poor risk patients will have already undergone coronary angiography if the criteria outlined in the sections relating to evolving myocardial infarction and completed infarction are used.

Management of the patient who has survived infarction and reached convalescence without important complications involves careful clinical judgment. Prognosis is best judged on the basis of the history of ischemic heart disease before the current infarction, the extent of left ventricular dysfunction and the presence of inducible myocardial ischemia. A number of studies have shown increased mortality and risk of recurrent infarction in patients with angina pectoris or a positive exercise test (58-60), although there is a significant incidence of false negative exercise tests in patients with three vessel coronary disease relatively early after myocardial infarction (61). Reduced ejection fraction at rest is also an independent marker of increased risk (62,63), particularly when associated with signs or symptoms of left ventricular failure at the time of hospitalization for acute myocardial infarction (64). Frequent or complex ventricular arrhythmias are an independent factor predicting increased risk (62,65), particularly when associated with a low ejection fraction (62). The occurrence of non-Q wave myocardial infarction carries an increased risk of reinfarction and enhanced mortality (66,67). A variety of schemes extensively discussed in many publications help to place patients into risk categories (68). If the risk is judged to be high, coronary angiography is indicated to determine whether the patient is a candidate for bypass surgery or percutaneous transluminal angioplasty.

Coronary angiography is frequently performed and may be justifiable in young patients after myocardial infarction because of the long-term morbidity that may follow another infarction; nevertheless, the late morbidity is low in uncomplicated myocardial infarction in young patients and the yield of multivessel disease on coronary angiography in such patients also tends to be low (69).

VII. Valvular Heart Disease

Class I

1. When valve surgery is being considered in the adult patient with chest discomfort or ECG changes, or both, suggesting coronary artery disease.
2. When valve surgery is being considered in male patients ≥ 35 years of age.

3. When valve surgery is being considered in female patients who are postmenopausal.

Class II

1. During left heart catheterization when aortic or mitral valve surgery is being considered in male patients <35 years of age.
2. During left heart catheterization when aortic or mitral valve surgery is being considered in female patients ≥ 40 years of age.
3. When one or more major risk factors for coronary artery disease are present (heavy smoking history, diabetes mellitus, hypertension, hyperlipidemia, strong family history of premature coronary artery disease) in adult patients of any age being considered for valve surgery.
4. During left heart catheterization when reoperation for aortic or mitral valve disease is being considered in patients who have not had coronary angiography for ≥ 1 year.
5. In the presence of infective endocarditis when there is evidence for coronary embolization.

Class III

1. When cardiac surgical treatment is planned for infective endocarditis in patients who are <35 years of age and have no evidence of coronary embolization.
2. When aortic or mitral valve surgery is being considered in female patients <40 years of age who have no evidence suggesting coronary artery disease.

Comments

In patients undergoing operation for valvular heart disease there is evidence that the presence of significant coronary artery disease not treated by coronary artery bypass grafting at the time of valve surgery adversely affects outcome (70). Surgical results in patients in whom valve replacement is combined with coronary artery bypass graft surgery are now generally comparable with those in patients having isolated valve replacement. Therefore, it is advisable to combine bypass graft surgery with valve replacement when these two conditions coexist.

In adult patients with aortic stenosis, there is general agreement that a relatively high incidence (about 50%) of coronary artery disease exists, in part because of the relatively advanced average age of such patients. Angina pectoris is often associated with coronary artery disease in patients with aortic stenosis, but there is a significant incidence ($\geq 25\%$) of coronary artery disease in patients who do not have angina pectoris (71). Moreover, some patients have angina pectoris because of an imbalance between myocardial oxygen demand and supply related to aortic valve obstruction alone. There is no available technique other than coronary angiography that allows identification of those patients with coronary artery disease.

There is a somewhat lower incidence of coronary artery disease in patients with aortic regurgitation (approximately 30%), and a significant fraction of these patients do not have angina pectoris (72). Coronary artery disease also occurs with considerable frequency in mitral valve disease (23 to 50%), and angina pectoris is also an unreliable marker of coronary artery disease in this setting. For example, in patients with mitral stenosis >40 years of age (average age 60 years), among the 28% of patients with significant coronary artery disease angiographically, nearly two-thirds did not have angina pectoris (73). It should be noted that in older studies, >50% narrowing of the coronary arteries was considered significant, whereas in more recent studies 70% narrowing (or >50% narrowing of the left main artery) was considered significant (71,73). Many past studies have recommended ≥ 40 years as the age at which coronary angiography should be carried out routinely before surgery for valvular heart disease, although recently ≥ 35 years has been advocated for male patients (74).

In summary, combined valve replacement and coronary bypass graft surgery is desirable in the patient with or without angina pectoris if significant underlying obstructive coronary artery disease is present. Therefore, in patients being considered for valvular heart surgery who are at risk for underlying coronary artery disease, investigation of the coronary circulation is warranted. Thus, most adult male patients and postmenopausal women should also have coronary angiography performed at the time of cardiac catheterization when valve replacement is being considered.

Infective endocarditis whether acute or subacute may produce valvular insufficiency that requires valve replacement. In some of these patients the endocarditis may result in one or more major coronary emboli. This development may result in the superimposition of the clinical picture of acute myocardial infarction in a patient with clearcut findings of infective endocarditis. More commonly, it results only in serial electrocardiographic evidence of Q wave or non-Q wave myocardial infarction. If valve replacement is being undertaken, it is desirable to evaluate the coronary anatomy in such patients to determine whether one or more proximal obstructive lesions are present that may warrant concomitant bypass graft surgery.

VIII. Known or Suspected Congenital Heart Disease

Class I

1. Evaluation of patients with congenital heart disease who have signs or symptoms suggesting associated atherosclerotic coronary artery disease.
2. Suspected congenital coronary anomalies such as congenital coronary artery stenosis, coronary arteriovenous fistula, supra-aortic stenosis and anomalous origin of left coronary artery, provided that aortography is not diagnostic.

3. When corrective open heart surgery for congenital heart disease is being planned in male patients >40 years or postmenopausal female patients.

Class II

The presence of forms of congenital heart disease frequently associated with coronary artery anomalies that may complicate surgical management (including tetralogy of Fallot, truncus arteriosus, transposition complexes, corrected [levo] transposition), provided that aortography is not diagnostic.

Class III

Coronary angiography is not routinely indicated in the evaluation of congenital heart disease.

Comments

The rationale for coronary angiography in some patients with congenital coronary lesions is similar to that for coronary atherosclerosis, that is, to assess the severity of the lesion and determine whether surgical treatment is indicated. The principal anomalies in this group are congenital coronary artery stenosis or atresia (75), coronary artery fistula (75), anomalous left coronary artery arising from the pulmonary artery (76) and anomalous left coronary artery arising from the right coronary artery or right sinus of Valsalva and passing between the aorta and right ventricular outflow tract (77). Unfortunately, the latter anomaly may present with sudden death after exertion, without prior warning (78).

Other anomalies of position or origin of the coronary arteries may cause no physiologic abnormality in themselves. Some, such as origin of the circumflex artery from the right sinus of Valsalva, are not associated with other congenital anomalies and present only as incidental findings that complicate the performance and interpretation of coronary angiograms. Others tend to occur with certain congenital anomalies, and because of anomalous position a coronary artery may be injured at the time of surgical correction of the associated anomaly, so that preoperative coronary angiography may be indicated. Most frequent in this category is anomalous origin of the left anterior descending coronary artery from the right coronary artery passing across the anterior right ventricle in patients with tetralogy of Fallot (79).

IX. Other Conditions

Class I

1. In diseases affecting the aorta when knowledge of the presence or extent of coronary artery involvement is necessary for management, (for example, the presence of aortic aneurysm or ascending aortic dissection), arteritis or homozygous type II hypercholesterolemia in which coronary artery involvement is suspected.

The latter includes the presence of Kawasaki's disease in patients who have angina and other evidence of myocardial ischemia or infarction.

2. The presence of left ventricular failure without obvious cause and adequate left ventricular systolic function (see section IVB, Class I, 4e).
3. When male patients who are ≥ 35 years of age or female patients who are postmenopausal with hypertrophic cardiomyopathy have angina pectoris uncontrolled by medical therapy, or are to undergo surgery for outflow tract obstruction.

Class II

1. The presence of dilated cardiomyopathy.
2. Recent blunt trauma to the chest and evidence of acute myocardial infarction in patients who have no evidence of preexisting coronary artery disease.
3. When male patients >35 years or postmenopausal female patients are to undergo other cardiac surgical procedures, such as pericardiectomy or removal of chronic pulmonary emboli.
4. Prospective immediate cardiac transplant male donors >35 or females >40 years of age.
5. Evaluation of asymptomatic patients with Kawasaki's disease who have coronary artery aneurysms on echocardiography.

Class III

None listed.

Comments

Most patients undergoing surgical treatment for aortic dissection do not require coronary angiography before the surgical procedure. However, in selected patients in whom the dissection is believed to involve a coronary artery, or in whom coronary artery disease is suspected, coronary angiography may be helpful in determining the most appropriate surgical approach. Patients with an aortic aneurysm frequently have concomitant coronary artery disease and may require coronary angiography before surgical correction of the aneurysm if they have evidence of myocardial ischemia, are men >35 years or postmenopausal women. Some patients with inflammatory processes affecting the aorta such as Takayasu's arteritis may have coronary artery involvement requiring coronary artery revascularization. In such patients, coronary angiography obviously is required before the surgical procedure. Kawasaki's disease can result in coronary artery aneurysm and coronary artery stenosis producing myocardial ischemia or silent occlusion and may require coronary angiographic assessment (80,81).

Significant coronary artery disease due to atherosclerosis has been found in approximately 25% of patients >45 years with hypertrophic cardiomyopathy who have undergone coronary angiography (82). Because symptoms due to coro-

nary artery disease and hypertrophic cardiomyopathy are similar, male patients >35 years and postmenopausal female patients with ischemic symptoms not well controlled with medical therapy may require coronary angiography. Coronary angiography also is indicated in patients of this age group with hypertrophic cardiomyopathy in whom a surgical procedure to correct outflow tract obstruction is planned.

The primary indications for coronary angiography in patients with a dilated form of cardiomyopathy are: 1) during consideration for cardiac transplantation and, 2) to differentiate idiopathic dilated cardiomyopathy from ischemic myocardial disease if the latter might be improved by revascularization. The differentiation of patients with ischemic myocardial disease from those with the dilated type of cardiomyopathy usually is not difficult because the great majority of the former patients also have angina or evidence of previous infarction (83). Furthermore, the management of those with ischemic myocardial disease and severe generalized left ventricular dysfunction without angina generally is the same as that of patients with dilated cardiomyopathy. Coronary angiography may be of value in those patients with clinical findings suggesting dilated cardiomyopathy who also have angina pectoris, left ventricular aneurysm or evidence of reversible ischemia who might be candidates for surgical revascularization if coronary artery disease were present.

Patients who have an acute myocardial infarction shortly after blunt chest trauma may have atherosclerotic coronary artery disease, but coronary artery obstruction has been reported in the absence of coronary atherosclerosis (84). Furthermore, myocardial contusion may stimulate acute myocardial infarction. Infrequently, coronary angiography is indicated in the management of such patients.

In patients undergoing cardiac operations such as pericardiectomy or removal of chronic pulmonary emboli (85), perioperative coronary angiography may be indicated in the coronary-prone age group.

Appendix A

1. *Venous access* is an important part of coronary angiography. A well functioning intravenous infusion line generally should be available before each procedure and continued for a short period after its termination.
2. *Hemodynamic assessment* is a routine part of selective coronary angiography. Before angiography, pressures in the left ventricle and aorta are measured and, depending on requirements in the individual patient, cardiac output may be determined.
3. *Left ventricular angiography* is normally a routine part of diagnostic selective coronary angiography, but may be excluded in certain high risk patients if recent information on left ventricular function is available from noninvasive studies. During left ventricular angiography, contrast medium is injected into the left ventricular cavity. From this visualization of the left ventricular chamber, an assessment is made of left ventricular size, global ventricular function (by calculating the ejection fraction), regional wall motion, mitral regurgitation, filling defects suggesting mural thrombus and so on. Other techniques, such as intravenous digital angiography or radionuclide angiography, are now also available in some centers to obtain this information.
4. *Right heart catheterization* is not routinely part of coronary angiography but is an associated procedure in selected patients. During right heart catheterization, intracardiac pressures, oxygen content in blood samples, dye-dilution curves and cardiac output may be obtained, as well as right ventricular or pulmonary artery angiography, or both, if needed. In situations in which right ventricular function may be abnormal (right ventricular infarction, tricuspid regurgitation, ventricular septal defect), pulmonary artery disease is suspected (pulmonary hypertension, pulmonary emboli) or heart failure is present, right heart catheterization should be a part of coronary angiography. Additionally, in patients with unusual risk related to bradycardia or various degrees of atrioventricular block, or in patients in unstable condition, right heart catheterization with a pacing catheter connected for standby pacing is an important safety procedure to help ensure lower risk during coronary angiography. Right heart catheterization also may be indicated in certain other settings (for example, suspected intracardiac shunt).
5. *Selective internal mammary angiography* usually is not performed routinely preoperatively when use of the internal mammary arteries is planned. It may be done in some patients when one of the internal mammary arteries has been previously used, or when previous traumatic chest injury or thoracic surgery may have damaged one of these vessels. It may also be done if subclavian artery stenosis is suspected from the presence of a bruit or difference in blood pressure between the two arms.
6. *Selective saphenous vein bypass graft or internal mammary artery angiography* is done as an associated procedure in patients with previous coronary bypass surgery.
7. *Pharmacologic studies* using ergonovine stress testing and the response to orally or parenterally administered nitroglycerin can be associated procedures used to identify the presence or absence of coronary artery spasm.
8. *Aortic root angiography* may be done to assess the ostia of the coronary arteries in relation to the aortic root in patients with suspected aortic aneurysm or dissection, and also in patients with associated aortic valve incompetence to assess the degree of regurgitation. In patients

with aortic stenosis, this associated procedure is sometimes useful in defining the size of the aortic anulus, the origins of the coronary arteries or the presence of supravulvar stenosis.

9. *Digital subtraction angiography* can be used to process images of selectively injected coronary arteries. In addition, digital subtraction angiography can be used to provide an assessment of carotid, femoral, renal or peripheral arteries in selected patients at the time of selective coronary angiography.
10. A number of *transcatheter procedures* for diagnosis or therapy may be included as associated procedures when there are indications for their use. These procedures include percutaneous transluminal coronary angioplasty, intracoronary administration of thrombolytic drugs, transcatheter ablation for arrhythmia control, myocardial biopsy and others.

Appendix B

Grading of Angina of Effort by the Canadian Cardiovascular Society*

- I. "Ordinary physical activity does not cause . . . angina . . .", such as walking and climbing stairs. Angina with strenuous or rapid or prolonged exertion at work or recreation.
- II. "Slight limitation of ordinary activity." Walking or climbing stairs rapidly, walking uphill, walking or stair climbing after meals, or in cold, or in wind, or under emotional stress or only during the few hours after awakening. Walking more than two blocks on the level and climbing more than one flight of ordinary stairs at a normal pace and in normal conditions.
- III. "Marked limitation of ordinary physical activity." Walking one to two blocks on the level and climbing one flight of stairs in normal conditions and at normal pace.
- IV. "Inability to carry on any physical activity without discomfort—anginal syndrome *may be* present at rest."

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